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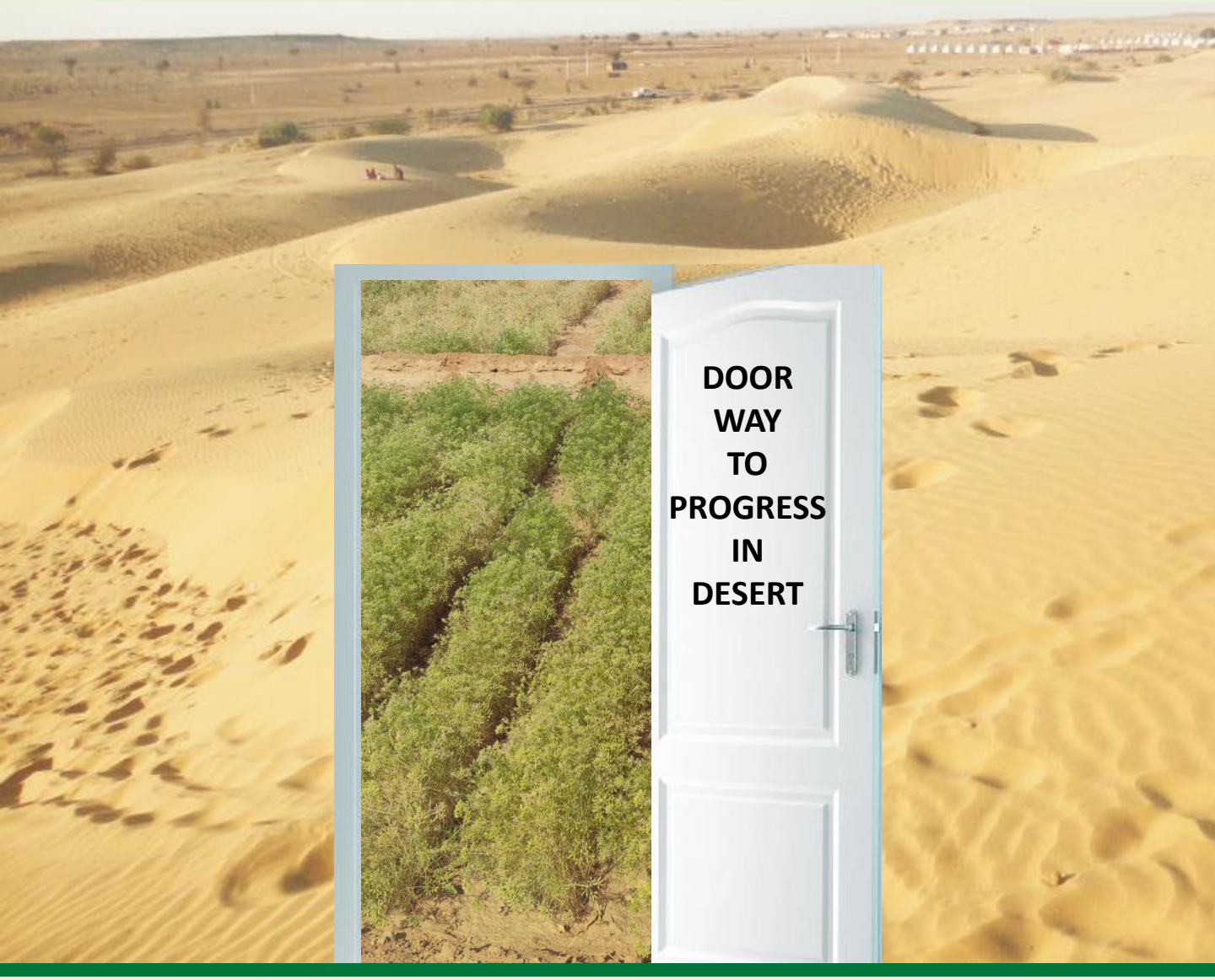

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From the desk of chairman

Dear Readers,

India is regarded as the 'Land of Spices' owing to its half of the global trading in spices. The states of Rajasthan and Gujarat have emerged as "Seed-Spice Bowl" and together contribute more than 80 per cent of total seed spices produced. Out of 63 spices grown in India, 20 are classified as seed spices of which 10 are prevalent in Rajasthan. Coriander, cumin, fennel and fenugreek are the major spices cultivated in large area while ajwain, dill, celery, nigella, anise and caraway belong to minor group of seed spices covering small acreage. Cumin is predominantly the main cash crop cultivated in hot arid zone of India, and Rajasthan shares around 63 percent of cultivated area of whole country.

Fenugreek is another commercially important spice crop due to its multifarious uses and Rajasthan state is contributing about 80 percent of the country's production. This issue of DEN highlights the seed spices of western Rajasthan. I wish the information provided in this issue will be beneficial to academicians, researchers and other stakeholders.

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Know Your Desert

Cumin: A Boon to Indian Arid Zone

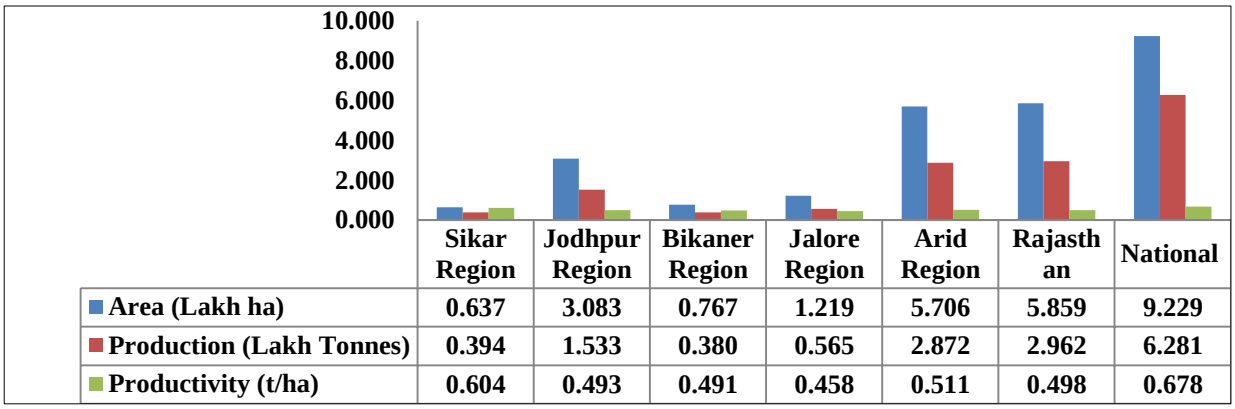
Spices are non-leafy parts like bud, fruit, seed, bark, rhizome, bulb of plants used for flavouring or seasoning. They are defined as vegetable products or mixtures thereof, free from extraneous matter, used for imparting aroma in foods, beverages and also as herbal medicines. Spices have a profound influence on the course of human civilization as they permeate our lives from birth to death. In everyday life, spices succor us, cure us, relax us, and excite us. Ancient people such as the Egyptians, the Arab, and the Roman made extensive uses of spices, not only to add flavour to foods and beverages but as medicines, disinfectants, incenses, stimulants, and even as aphrodisiac agents. No wonder they were sought after in the same manner as gold and precious metals.

India is known as the 'Land of Spices' due to its rich repository of spices. Among the wide varieties of spice crops, there is a distinct group, 'seed-spices' which constitutes all the annual crops whose dried seeds are used as spices. Out of the 63 spices grown in India, 20 are classified as seed-spices with 36 percent share in area and 17 percent share in the production of the total spices in India. The main crops with a larger area under cultivation are cumin, coriander, fenugreek, and fennel, whereas minor crops covering small acreage are ajwain, dill seed, nigella, anise, and celery. Most of the seed spices are grown in arid and semi-arid areas of India. Rajasthan and Gujarat states have emerged as "Seed-Spice Bowl "and contribute more than 80 percent of total seed spices produced in the country. Indian hot arid environment is very distinctive for harsh climatic conditions comprising high temperature, dry weather, high wind speed, low rainfall, sandy soils, low soil fertility, saline soils & water, limited groundwater resource, undulating typography etc. All these factors create complex, challenging situations that limit agriculture productivity and crop choice in the hot arid zone. But, at the same time, the typical arid situations are very favorable for few cash crops that cannot be grown successfully in resource-rich productive environments, e.g., cumin, which makes the Indian hot arid zone 'Land of Seed Spices'.

Cumin is predominantly cultivated in the hot arid zone of India. World's largest consumer and exporter of cumin is India, where it is grown on 9.22 lakh ha. Out of the total cultivated area of cumin in-country, Rajasthan share around 63 % (5.85 lakhs ha), and the arid region of Rajasthan holds around 97 % (5.70 lakh ha) area of the state (Fig. 1). Annually 2.87 lakh tonnes of cumin seed are harvested from the arid zone of the country with productivity levels of below 0.5 t ha^{-1}. However, it fetches high value in the market due to the quality of the seed produced in the region. As a result, the annual export is of around 2.10 lakh tonnes worth value Rs. 3225 crores (2019-20) from India.

Cumin in Rajasthan, is cultivated mainly in districts viz., Jodhpur and Barmer (Jodhpur Region); Nagaur (Sikar Region); Bikaner, Churu and Jaisalmer (Bikaner Region); Jalore, Pali and Sirohi (Jalore Region) (Fig. 1) during winter months under irrigation. Generally, very low temperatures can cause frost damage, and high humidity increases *Alternaria* blight incidence in the crop. Hence, arid zone having dry weather, cool temperature, and frost free environment makes favorable agro-climatic situations for quality cumin production with minimum risk. Cumin research and developmental work started way back in the 1970s in India.

Research advancements have delivered high-yielding varieties, better production and protection packages, and post-harvest management practices, but there is still a lot to be done.



	Sikar Region	Jodhpur Region	Bikaner Region	Jalore Region	Arid Region	Rajasthan	National
Area (Lakh ha)	0.637	3.083	0.767	1.219	5.706	5.859	9.229
Production (Lakh Tonnes)	0.394	1.533	0.380	0.565	2.872	2.962	6.281
Productivity (t/ha)	0.604	0.493	0.491	0.458	0.511	0.498	0.678

Fig 1- Area, production and productivity of cumin in arid region

Cumin Crop Profile

Cumin (*Cuminum cyminum* L.) belongs to the Apiaceae family and has only one wild relative i.e., *C. setifolium* (Boiss.) Koso-Pol. which bears hairs on the seeds. *C. cyminum* is geographically distributed in the Middle East and western Asia, specifically in hot arid environment. It is a short-statured plant of height up to 50 cm with few branches and low biomass of thin short leaves, seeds emerge on umbels. It germinates in 10-20 days, depending upon local conditions. Cumin crop is highly susceptible to major diseases like *Fusarium* wilt and *Alternaria* blight and sucking pest mainly aphids. In cultivated genotypes of cumin, flower emergence occurs in around 70-75 days after sowing; with reproductive stage of approximately 50-60 days and matures in 120-135 days.

Cumin Cultivation

The cool temperature during November month in the western arid region is best for sowing. For sowing, farmers usually broadcast the seed in dry fields and irrigate just after creating a thin layer of soil over the seed. Around 12-15 kg seed ha^{-1} is required for sowing. Seed treatment is essential to prevent/reduces the incidence of fungal diseases in roots. Depending on water availability and land configuration, both flood and sprinkler irrigation are practiced. As germination is slow in cumin, second irrigation after 7-10 days is essential to moist the upper layer of soil for ease of germination. Prophylactic measures are recommended to minimize chances of *Alternaria* blight incidence at the vegetative or reproductive stage. After the incidence, curative measures of *Alternaria* blight management are also recommended. However, pesticide residue is a critical factor for the export of cumin.

Many high-yielding cultivars have been developed under the umbrella of AICRP on Spices. Among others, the cultivar 'Gujarat Cumin 4' (GC-4) was developed in 2006. Due to its high yield and tolerance to *Fusarium* wilt, GC-4 is very popular among farmers of arid regions. Although GC-4 is susceptible to *Alternaria* blight, however low humidity in the arid areas creates weather conditions unfavorable for the spread of blight. Hence, in arid regions, the pesticide load remains low in cumin seeds, making it best for human consumption and export. The aroma in cumin is due to essential oil content. In arid regions, the low temperature during seed setting and pre-maturity stage is favorable for essential oil synthesis in cumin seeds.

An average 0.5-1.0 t ha^{-1} cumin seed can be harvested with the recommended package of practices. The average price of cumin seed in the domestic market ranges between Rs. 120-140 kg^{-1}. Hence with a cost cultivation of Rs. 40,000 ha^{-1}, its cultivation can fetch a net income of around Rs. 1.0 lakh ha^{-1}. Thus cumin is one of the most economical crops with a benefit: cost ratio of above 3.0.

Constraints for Cumin Production

The sensitivity of cumin to various biotic and abiotic stresses makes it one of the riskiest crops in arid regions. Although, arid regions are most favorable for cumin cultivation, however, local resources, weather conditions, and soil and water quality affect crop productivity. The sensitivity of the crop to diseases, pests, salinity, frost, and high temperature are the broad defining criteria for its cultivation. Cumin needs 4-5 irrigations during the whole crop duration of 120-135 days. Cloudy weather during flowering is favorable for blight incidence hence, it needs 2-3 prophylactic sprays of pesticides for minimizing the risk. In areas where humidity levels are high, more prophylactic sprays may be required. Further, crop productivity is also reduced by high temperatures and dry winds during March. Therefore, the cultivation of cumin, the most important cash crop of the region, is always risky and costly to resource-limited farmers of the arid areas. Although, assured crop cultivation of cumin is a dream, technological interventions can minimize the risk. Considering the limited natural resources, there is a need to develop technical packages which can fit well with the available resources to give economic yields above the existing average in a shorter time. Furthermore, as crop duration is deciding factor for cultivar/crop input efficiency, reducing crop duration can significantly minimize the risk and assure returns of cumin cultivation.

Technological Innovations

Cumin genetic resources are very narrow in terms of variability for agro-morphological traits. Hence, the varieties in vogue are developed mainly through selection or mutation. Although recombination in cumin is not possible due to small flower size, natural variants/mutants showing transgressive traits in the desired direction are observed in cropped areas. At ICAR-CAZRI, Jodhpur, a genotype 'CZC-94' has been developed, showing earliness in flowering (40-42 days) and maturity (90-105 days) (Fig. 2). Furthermore, small plot trials and large-scale field trials have shown that the genotype can be grown under timely sown and late planting until mid-December. Hence genotype 'CZC-94', being shorter in duration, can be cultivated in both timely sown-early harvest and late sown-timely harvest models. However, this bimodal cumin cultivation is not feasible with others cultivars, including GC-4, because of a longer crop duration of 120-130 days. In western Rajasthan, a rainfed Kharif crop matures in 60-75 days, whereas Rabi crops take almost 180 days from mid of October to the middle of April. However, with this early maturing cumin genotype (CZC-94), land and water use efficiencies improved therefore, farmers' income can be enhanced and assured.

Genotype 'CZC-94' of cumin has the following advantage over prevailing genotypes

- In arid regions where cotton is being grown, the cotton-cumin crop sequence is impossible due to overlapping cotton harvesting and cumin sowing. However, early maturing short duration cumin cultivars can address the problem by offering late sowing of cumin.

- Timely sown early maturing cumin cultivars of 100 days can vacate fields early by February first week for summer cucurbits.
- Cropping intensity can be increased by adopting three early crops in succession, e.g., mung bean (July to September) followed by carrot (October to December) and cumin (January to March) in arid areas where underground water is available for irrigation.
- Early cumin cultivars of 100 days may need less water and less pest/disease management spray loads, minimizing the input cost and compensating the yield compromise over popular cultivars.
- As crop standing days in the field are reduced significantly with early cultivars, the risk of cumin crop loss due to Alternaria blight in cloudy weather and hail storms due to western disturbances can be minimized.
- Early harvest can also escape the heat stress encountered in arid regions that reduces the crop yield by hampering the grain filling in tertiary umbels of cumin.
- Early cultivars can also provide opportunities to expand cumin in unconventional areas with dry conditions, but the cold period is less.
- CZC-94 can be grown from mid-October to the beginning of January as its germination is fast and less influenced by the soil temperature.

Fig 2- CZC- 94: An early maturing genotype developed by ICAR-CAZRI, Jodhpur

Immediate Needs

Cumin is the main cash crop of arid regions. The current seed replacement rate needs to be improved. The quality seed availability by the public sector, mainly state seed corporations and SAU's or other government institutes like ICAR-CAZRI, Jodhpur, ICAR-NRCSS, Ajmer is limited.

Private players primarily meet the seed demand, and they sell their varieties. The public-private partnership model of growing seed crops at farmer's fields under the 'seed village concept' can improve the improved seed supply. Improved seed drills by farmers will save the seed and reduce the input cost as seed cost is around Rs. 300 kg^{-1}, and saving 3-4 kg of seed ha^{-1} is a significant saving for arid farmers. Line sowing can also increase the labour efficiency in performing the regular operation of weeding and inter-culturing. Cultivar diversity is also needed; as GC-4 is the only variety under cultivation in the region, there is a need to identify new cultivar to break this mono variety cultivation practice to improve productivity levels.

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Know Your Desert Plant

Enhancing Productivity of Fenugreek (*Trigonella foenum-graecum*) in semi-arid region of India

Fenugreek (*Trigonella foenum-graecum* L.) commonly known as *methi* is used as a condiment for flavouring of foods as well as for medicinal purposes.South-Europe, Mediterranean area and western Asia are the centres of origin of fenugreek. India is also to be a native of fenugreek and found growing wild in Kashmir, Punjab and Upper Gangetic Plains. The genus *Trigonella* consists of 50 species, most of which have an oriental origin in the Iranian Indian region. Of these, eleven species occur in India, out of which *Trigonella foenum-graecum* L. (common fenugreek) and *Trigonella corniculata* L. (*Kasuri* type fenugreek) are cultivated in India. Major fenugreek producing countries are India, Argentina, Egypt, France, Spain, Turkey, Morocco and China. India is the largest producer of fenugreek in the world. In India, Rajasthan, Gujarat, Uttarakhand, Uttar Pradesh, Madhya Pradesh, Maharashtra, Haryana and Punjab are the major fenugreek producing states. Rajasthan is the fenugreek bowl of the country, contributing about 80% to the country's production. Fenugreek is commercially important spice crop due to its multifarious uses and is extensively grown in almost every part of the country during winter season for seeds, tender shoots, and fresh leaves (Fig 3.). Around 1,82,170 tonnes of fenugreek was produced from 1,26,294 ha area during 2019-20. The current productivity of fenugreek is 1442 kg ha^{-1} in 2019-20. In Rajasthan, it is grown in 52,661 ha area producing 66,742 MT with the productivity of 1267 kg ha^{-1}. Fenugreek rank third among seed spices. Kota and Jhunjhunu are the major fenugreek producing districts in Rajasthan.

Fig 3- Fresh leaves and seeds of fenugreek

Immediate Needs

Fenugreek is having a number of good varieties suitable for different agro climate regions. There are many varieties released for cultivation in different areas (Table 1).

Table 1- Varieties of Fenugreek released for cultivation in different states

States	Variety	Maturity period (Days)	Yield (t ha^{-1})
Rajasthan	RMt -1	140-150	1.47
	RMt - 143	140-150	1.6
	RMt - 305	-	1.3
	RMt-361	-	1.84
	Ajmer Fenugreek 1(AFg-1)	137	2.7-2 0
	Ajmer Fenugreek 2(AFg-2)	138	1.81
	Ajmer Fenugreek 3(AFg-3)	130	1.8-2.0
	Ajmer Fenugreek 4(AFg-4)	-	1.93
	Ajmer Fenugreek 5(AFg-5)	-	1.7
Gujarat	GM-1	-	1.86
Tamil Nadu	CO-1	95	0.68
Bihar	Rajandra Kranti	120	1.25
Andhra Pradesh	Lam Selection -1	90	0.74
Haryana	Hisar Sonali	140-150	1.9
	Hisar Suvarna	-	1.9-2.0
	Hisar Mukta	-	2.0-2.3
	Hisar Madhavi (HM-350)	-	1.9-2.0
Uttarakhand	Pant Ragini	170-175	-
Delhi	Pusa Early Bunching	100-125	1.2
	Pusa Kasuri	-	0.5-0.7

Cultivation Practice

***Climate*:** Fenugreek requires cool climate for its better growth and development. A cool growing season without extremes of temperature is favorable for best plant development. It has wider adaptability and crop can be grown successfully both in tropical and temperate regions. In India, it is mainly grown as a rabi season but in south India, it is also grown in rainy season. The crop can be grown in areas of low to moderate rainfall but cannot withstand heavy rainfall. Continuous moist and cloudy weather invites insect pests and number of diseases. Dry weather during crop maturity is essential for harvesting better seed yield.

Soil: Fenugreek can be grown in almost all type of soils having good drainage facilities but grow best on well drained loamy soils. Organic matter rich clay-loam soil may also be suitable for its cultivation but the crop does not thrive best in sandy or gravely soils. Although the crop is tolerant to salinity up to 8.4 pH, but in neutral soils having a pH range from 6.5 to 7.5 it gives higher yield with better quality of leaves. The crop is fairly tolerant to salinity, however, high saline, sodic and acidic soils are to be avoided.

Cropping system: Fenugreek can be grown as mixed or intercrop. Being leguminous crop, it fits well as component crop for most of inter cropping systems involving fennel, coriander, ajwain, dill and winter vegetable crops. Likewise, crops should be grown as per standard principal of crop rotation. Some of the crop rotation systems suggested are: Maize / Pearl millet Fenugreek; Sesame Fenugreek; Sesame Fenugreek Summer Maize

Land preparation: The land should be well prepared for better germination of seeds and growth of plant. A total of 3-4 ploughings are required. The first ploughing should be done by soil turning plough followed by 2-3 ploughing with harrow to bring the soil to a fine tilth. At the time of sowing, there should be good moisture in the soil for better germination of seed. Planking should be done after every ploughing to conserve soil moisture.

***Sowing time*:** Fenugreek, being cool season crop, is sown in the months of October and November in northern plains, whereas, in hilly tracts, it is sown from March to May. In areas with mild climate, fenugreek for fresh greens leaves may be grown round the year except extreme hot months of summer and rainy season. In southern states of India, particularly Karnataka, Andhra Pradesh and Tamil Nadu, fenugreek is sown twice, once in rabi (September–December) and again in Kharif season (June–July). *Kasuri* type varieties require preferably extra cool weather for longer duration.

***Seed rate*:** Proper seed rate should be maintained to raise a healthy crop for better yield with quality produce. If it is less than the requirement, the plant spacing will be more and crop density will be less. Higher seed rate leads to high plant population resulting in poor plant growth and poor quality produce due to increase competition for water, nutrition, light etc. Common fenugreek seed rate is 20 – 25 kg ha^{-1} and for Kasuri methi it 10–12 kg ha^{-1}.

Seed treatment: Being a legume crop, fenugreek fixes nitrogen about 283 kg ha^{-1} $year^{-1}$ from the atmosphere into the soil. The role of *Rhizobium* in fenugreek production is well established, and thus inoculation of seed before sowing is beneficial for getting higher seed yield. Seeds should be treated with *Rhizobium meliloti* local culture prior to sowing, especially when the crop is sown in new field. Seed should be treated with bevistin or thiram @ 2.0g kg^{-1} seed for the control of early fungal diseases.

Method of sowing: Fenugreek can be sown either in lines or by broadcasting seeds in well-prepared flat seedbeds and raking the bed surface prudently. However, sowing in lines is comparatively better than the broadcasting since it facilitates the intercultural operations, like hoeing and weeding. Line to line spacing of 25-30 cm is required and later the plants are

to maintain 10-15 cm spacing within the lines. The seed germinates in about 5-7 days of sowing. Although the depth of the sowing seeds depends on soil type and soil moisture at the time of sowing, but being small size, the seeds of common fenugreek are usually sown at a depth of 2-3 cm and *kasuri* fenugreek at 1.0-1.5 cm. Seed yield was highest at spacing of 20 cm and without harvesting leaves.

Manures and fertilizers: To maintain a steady state of productivity, application of FYM (10 t ha^{-1}) has a beneficial effect on the enhancement of vegetative growth and resulted in higher dry matter production of fenugreek. Application of 1 t $ha^{-1}$of neem cake has also proved beneficial. The microbial inoculation with *Azospirillum*, *Azotobactor* spp. and *Rhizobium* has been reported to be suitable means for organic cultivation of fenugreek. Doses of fertilizer depend on fertility status of the soil, type of soil and variety to be grown. The fertilizer recommendation for different state is given in Table 2.

Table 2- Fertilizer recommendations for fenugreek in different states

State	Fertilizer doses (per ha)
Rajasthan	40 kg N, 40 kg P_2O_5
Gujarat	40 kg N, 40 kg P_2O_5
Bihar	40 kg N, 60 kg P_2O_5, 20 kg K_2O
Uttar Pradesh	60 : 50 : 10 kg NPK
Tamil Nadu	N 50 kg , P 25 kg and K 40 kg
Haryana	40 kg P_2O_5

Irrigation: Fenugreek, being primarily an irrigated crop, requires light irrigations at frequent intervals for its quick growth but can also be cultivated under rain fed conditions in certain parts of the country. Usually the crop is sown when the field is having plenty of soil moisture so irrigation is not applied unless the seedling attain 2–4 true leaves. However, if the initial moisture in the field at sowing is inadequate, a light irrigation should be applied very soon after sowing and should be followed by another light irrigation on third day to facilitate rapid and uniform germination. Subsequent irrigations are given at 12 -15 days interval, depending on soil type, season, rainfall, and other temporary weather conditions. Frequent and light irrigations are essential for quick foliage growth if the crop is cultivated for green leaves and each cutting should be followed by a light irrigation. The early growth period and seed setting are the critical stages for irrigation in the crop grown exclusively for grain or seed purpose. Too much of irrigation is also as harmful as the scarcity of moisture or excessive moisture in any form and at any stage increases the incidence of root rot and powdery mildew especially at flowering stage. Care should be taken to avoid water stress at pod and seed development stages. Normally 6-7 irrigations are required in light soil and 4-5 irrigations are needed in heavy soils.

Weed management: Hoeing and weeding during early stages of plant growth are very essential to make the soil loose around the roots and to control the weeds, since weeds due to slow growth of fenugreek seedlings may pose problem in initial stages, however, in later stages, when the crop canopy is fully developed, weeding is not at all required as the crop itself suppresses the weeds. Initial 30-40 days were identified as a critical period with respect to crop weed competition in fenugreek. Generally 2–3 hand weeding are required to keep the crop weed free and reducing the crop weed competition for resources like nutrients, moisture, light and others.

Two weeding and hoeing, first at 15 – 20 days after sowing, along with thinning of the plants and second weeding at 40-50 days after sowing should be done for healthy crop and higher yield. Integrated weed management using pre-sowing application of pendimethalin @ 1 kg ha^{-1} is very effective method of weed control for realizing higher yield and benefit in fenugreek cultivation. Pre emergence application of oxadiargyl @ 0.075 kg ha^{-1} just after sowing with one hand weeding at 45 DAS is very effective for weed management in fenugreek.

Plant protection measures: Fenugreek crop is generally less affected by insect-pests and diseases, however, a few of that sporadically harm the crop are aphids, leaf eating caterpillars, pod borers, mites, powdery mildew, downey mildew and root rot. The plant protection measures should include selection of resistant varieties, crop management practices such as time of sowing, balanced nutrition, crop rotation, green manuring etc. for reducing the incidence of diseases and pests and adoption of different type of measures to control them or to manage them below economic threshold level (Table 3).

Table 3- Plant protection measures in fenugreek

		Control
Insect-pests	Aphids	• Spray imidachlorprid 0.005% or thiomethoxan 0.025 % or dimethoate (0.33%). Repeat second spray after 10 days if necessary. • Application of fish oil, resin soap or neem seed kernel extract (NSKE 5 %), neem oil (2%) at early stage of population build up give good results. • Excess application of nitrogenous fertilizer like urea, ammonium sulphate and irrigation makes plant succulent and subsequently higher insect population build up. Hencefertilizers should be applied judiciously.
	Leaf eating caterpillar	• Destroy the egg mass and gregarious young larvae • Hand picking and killing of large larvae • Spray neem seed kernel extract (NSKS 5%) or neem oil 2% in the early stage of larvae development. • Use of nuclear polyhydrosis virus (NPV) @ 250 LE/ha and Beaveriabassiana @ 10^{10} spores/ml is an effective biological control. • Spray quinalphos 0.05 % • Monitoring and management of adult population through pheromone or light traps.
	Pod borer	• Monitor and manage adult population through pheromone or light traps. • Release of Trichogrammachilanis @ 50,000 eggs/week, spray of Beaveriabassiana @ 10^{10} spores/ml or Ha NPV @ 250 LE/ha is an effective biological control. • Spray of NSKE 5% or neem oil 2% controls the pod bores effectively when population builds up is at low level. • Spray quinalphos 0.05% or monocrotophos 0.04% when population reaches at higher level.
	Jassids (Empoasea spp.)	• Spray quinalphos 0.05% for effective control of jassids.
	White fly	Spray imidachlorprid 0.005% or thiomethoxan 0.025 or dimethoate 0.03% at initial stage of infestation with 400-500 liters of solution made in water is sufficient to cover one hectare area.
	Leaf Minor	• Spray dimethoate 0.03% or chlorpyriphos 0.05%. Make solution of insecticide in 400-500 liters of water to spray in one hectare area
	Mites	• Spray 0.005 % ethion or • 0.07 % dicofol or • 0.03 % phosphomidon for the control of mites measured quantity of insecticide should be dissolved in 400-500 liters of water apply in an area of one hectare. • Neem oil (2%) mites can also be controlled by spray of neem oil (2%) spray should be applied at initial stage of infestation for effecting control of mites.

Diseases	Root rot	This disease can be controlled by seed treatment with thiram or captain @ 2-3 g/kg of seed, application of neem cake @ 150 kg/ha combined with seed pelleting with antagonistics like *Trichodermaviride*, *T. harizianum* (talk bases formulatin 4g./kg of seed) followed by soil application of neem cake 150 kg/ha.(Ravindran*et al.*2001).Drenching twice with carbendazim(0.1%), first at initial appearance and second after one month with carbendazim or brassical (0.1%).Deep summer ploughing of field and adoption of crop rotation can minimize disease incidence. Use of bio-inoculants *Azospirillum* or *Azotobactor* also plays significant role in reducing incidence of root rot.
	Powdery mildew	Crop should be dusted with 300 mesh Sulphur dust @ 20-25 kg/ha to control the disease as soon as the symptoms are noticed. Spraying of wettable sulphur or dinocap can also be used to control the disease @ 20-25 g per 10 litre of water at the initial stage of this disease. If needed two more sprays should be given at an interval of 15 days after firs spray.
	Downey mildew	spraying Difoltan @ 0.2% or any other copper fungicide
	Damping off	Cultural operations like crop rotation and removal of diseased plants are effective and to minimize the source of infection seed treatment with Benomyl(3g/kg seed) or Carbendazim (3g/kg seed) is recommended.Use of soil amendments like neem cake @ 10 q / ha and farmyard manure @ 10 – 15 t /ha and adoption of proper crop rotation and deep summer ploughing is beneficial in the management of this disease. The antagonistic fungus *Trichodermaviride* and soil application of neem cake effectively control the disease.

Harvesting and Yield

The common fenugreek becomes ready for cutting fresh green leaves and young shoots in about 20 days after sowing while *kasuri* type fenugreek is ready in 25-30 days after sowing and subsequent cuttings may be taken at an interval of 15-20 days. The crop when grown for dual purposes after taking one cutting, which does not affect the seed yield, is left for seed production. The crop after harvest is bunched and marketed. The cutting is usually done with sharp knife by leaving stubs 3-4 cm above the ground level and after taking 4-5 cutting the crop grown exclusively for green leaves is uprooted. Common fenugreek can be harvested by clipping the young plants from the base and the clipped plants are allowed to grow further and their tops are nipped periodically until flowering. If fenugreek is harvested late, its leaves develop a bitter taste. Depending upon variety and season of growing the crop grow for grain takes about 80-125 days from sowing to harvesting. The entire plants is either pulled out or cut from the base with sickle when 70 % of the pods turn yellow, and made into small bundles for drying them in sun. Seeds are separated manually or winnowing by thresher. The grain/seed is dried up to 7-8% moisture, cleaned, graded and packed in different type of packages as per the requirement viz., plastic bags, cloth bags, gunny bags lined with polythene, CAP/MAP, vacuum packages etc. Under irrigated conditions, the common type fenugreek varieties normally give a fresh green leaf and seed yield of 7.0 -8.0 t ha^{-1}, 1.5-2.0 t ha^{-1}, respectively, and *kasuri* type 8.0-10.0 t ha^{-1} green leaves. However, higher yield can further be expected under good management practices.

Post-harvest Management

Keeping in view, the requirement of targeted market, post-harvest operations are advised to follow suitably for green leaves as vegetable, dehydrated leaves and seeds. In case of fresh greens, the edible portions are the tender leaves and stem, which are cut to length of about 7-10 cm. After harvesting, the yellow, diseased and damaged leaves are trimmed off and thereby healthy and disease free leaves are tied into small bunches for the convenience in handling and marketing. Since the dried leaves can be stored for one year for further use in off season, the

fenugreek leaves are sun–dried or dehydrated in a suitable dehydrator. However, during dehydration, chlorophyll is oxidized and ascorbic acid is lost, so as to retain green color of leaves, blanching in boiling water (80°C) for 3-6 minutes can be practiced. The palatability of fenugreek leaves improve with steaming and with addition of seasoning rather than with boiling or frying. The average vitamin C value in fenugreek leaves is 43.10 mg / 100 g and after boiling in water or steaming and then frying, the leaves lose 10.8 % and 7.4 % of this vitamin, respectively.

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Technological options

Unraveling the Diseases of Seed Spices in Arid Zone

The seed spices constitute an important group of agricultural commodities and play a significant role in our national economy. India is largest producer and consumer in the world, but presently, there has been low productivity of seed spices. There has been ever increasing demand of seed spices and importing country look at India as consistent source, which export raw spices as well as value added items to nearly 70 countries of the world. Lack of high yielding strains, improper nutrient management and occurrence of many diseases at various stages of crop growth are principle constraints to achieve high productivity of seed spices. Efforts have been made to compile available information on various aspects of important diseases of these valuable foreign exchange earning spice crops. Such information in the form of technologies will be fruitful for research workers for increasing profitability of seed spices crops especially aimed at improving the productivity and quality with reference to export and domestic demand.

Occurrence of diseases like wilt, blight and powdery mildew in cumin; wilt, powdery mildew and stem gall in coriander; blight and gummosis in fennel, and powdery mildew, downy mildew and mycoplasma-like organism (MLO) in fenugreek along with improper nutrient management are the two major reasons for low productivity of spice crops (Fig 4.). Cumin crop frequently suffers heavy loss in yield and deteriorating its quality of the produce due to low organic matter, low microbial population and poor moisture retention capacity. Further, repeated cultivation of susceptible genotypes have made soils conducive to wilt, the most important disease due to a soil borne pathogen *Fusarium*. Preliminary surveys revealed losses of about 5 to 25% in north Gujarat and 5 to 60 % in Rajasthan. However, infection may vary from 25 to 40 % and may be as high as 70 % in some cases.

Fig 4- Powdery mildew of fenugreek and Stem gall of coriander

In arid districts of Rajasthan, where cumin is extensively cultivated as a cash crop, approximately 40% yield losses were recorded. Frequently, growers are left with no alternative except to abandon its cultivation after a few successive years of cropping. The plants are affected at all growth stages, but the severity of wilt increases with the plant age. Generally when the crop is about one-month old the disease appears in the field. When plants attain a height of 2.5 – 5.0 cm, they wilt and die (Fig. 5.). In the severe stages, the tips of plants and leaves droop down leading to total mortality of the plants. Such plants can easily be pulled out of the soil. The roots of diseased plants bear dark brown markings. Sometimes, only partial wilting is observed. If the plants are infected at flowering stage, they remain sterile. Seeds if formed are thin, small and shriveled. In partially wilted plants, growth is arrested and the leaves become pinkish yellow in color. The predominant soil-borne nature and longer period of survival of resting structures of *Fusarium* in the soil have lessened the efforts to manage this disease for profitable cultivation. Many folk songs in Rajasthan and Gujarat depict the plight of resource deficient farmers.

Fig 5- Patches of wilt and *Alternaria* blight of cumin

Alternaria blight (*Alterneria brunsii*) (Fig 5.) is considered to be the most devastating disease of cumin in sub-tropical countries. This disease is quite prevalent and destructive as it affects all above ground plant parts including seed, thus, causing direct yield loss. Losses up to 70% have been reported and often responsible for total failure of crop. It was reported from Rajasthan in 1955. The pathogen causes minute scattered necrotic areas on all above ground plant parts, which soon turn purple at advanced stages and later turn brown to black and the affected parts gets quickly blighted. In Rajasthan, it mostly appears during February-March and become serious under humid and cloudy weather. The blight occurrence in the major growing districts of Rajasthan and Gujarat were recorded up to 33.6%. In the absence of any one effective way of managing wilt, major research efforts were diverted to identify resistant sources and then to use them in resistance breeding programme. Though, a few high yielding cultivars of cumin, viz., GC-1, GC-3, RZ-19 and GC-4 have been released in last few decades.

A negative correlation was observed between volatile oil content and resistance to wilt in cumin genotypes. Soaking cumin seeds in ethephon (800 ppm) increased plant resistance to wilt. Among the cultural methods of management, rotation with non-host crops has been found to be the most effective way of managing this disease in the same. Rotating cumin fields with mustard and pearl millet in winter and rainy season, respectively has been found to keep incidence of wilt under check. In arid region, where intense solar irradiations and high temperatures are amply available during summer months, harnessing solar heat has been found effective in minimizing wilt incidence in the field. In such region, two or three summer ploughing decreased the wilt incidence significantly. A significant reduction in wilt incidence and improvement in seed yield of cumin was recorded with three compared to one summer

ploughing. Incorporation of cruciferous amendment also enhanced the population of antagonistic actinomycetes in the soil. Combining summer irrigation with amendment of cruciferous residues during May or June was found highly effective in reducing *Fusarium* population in the field. Amendment of soil with a combination of mustard residues and mustard oil-cake (2.5 + 0.5 t ha^{-1}) was effective in control of *Fusarium* population in soil and incidence of wilt on cumin. This cost effective and efficient method is a practical way of control of wilts diseases because mustard residues are amply available in the region where cumin is cultivated. Disease management by integrated approach using both biocontrol agents and pesticides have effectively managed wilt, blight, powdery mildew, downy mildew and aphids which are the most devastating biotic stresses in majority of seed spices. Concerted efforts are needed to evolve appropriate technology for their effective control or varieties which can tolerate or resist these diseases.

Methodology developed by ICAR-CAZRI, Jodhpur is included in package of practices and recommended for cumin wilt management. Application of *Trichoderma harzianum* as seed treatment @ 6g kg^{-1} seed and soil application @ 1.0 kg ha^{-1} mixed with 50 kg of FYM at the time of sowing and adoption of soil solarization in combination with oil cakes has been found highly effective for managing soil borne plant pathogens of the arid crops. Developing Good Agricultural Practices and Integrated disease and pest management programme needs to be strengthened with the use of biocontrol agents for pest and disease resistance. The epidemiology study of wilt and blight diseases recommended that the wilt of cumin can effectively be managed by following management practices on II week of December, III week of December and I week of January while the *Alternaria* blight of cumin can effectively be managed following management practices on III week of January, I week of February and IV week of February. Recently ICAR-CAZRI developed an IPM package for the management of major diseases of cumin which is "Soil application of neem cake @ 250 kg ha^{-1} and vermicompost @ 2 t ha^{-1}, seed treatment with *Trichoderma viride* @ 4 ml kg^{-1} seed followed by one spray each of dithane M-45 2.5 g lit^{-1} mixed with dinocap (Karathane) @ 300 ml ha^{-1} at 45 days after sowing (DAS), imidacloprid 17.8SL @ 333ml ha^{-1} at 55 DAS and neem oil (2%) @ 5 ml lit^{-1} at 50 and 60 DAS." Some mathematical forecasting models were also developed by ICAR-CAZRI for the better management of the cumin wilt and blight diseases.

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Events

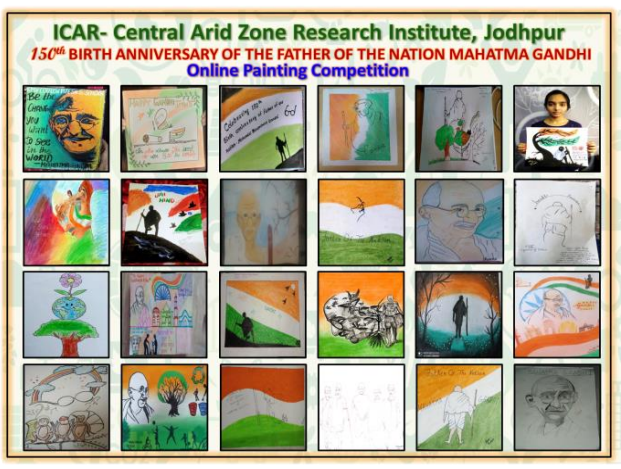
World Ozone Day

Celebrated the World Ozone Day on September 16, 2020 on the theme "*Ozone for life: 35 years of Ozone Layer Protection*" through a webinar. The Guest Speaker Dr. Usha Mina, Associate Professor, School of Environmental Sciences & ENVIS Co-cordinator, JNU, New Delhi elaborated the role of Ozone layer in stratosphere and troposphere layer of the atmosphere, its importance, process, causes and effects. She briefed how the expansion of ozone hole reflects the adverse effects on agriculture, health, economy and biodiversity of natural ecosystem. She

advocated few beneficial recommendations like use of equipments which are 'ozone friendly', 'HCFC free' or 'energy efficient'. Dr. C.B. Pandey, Principal Scientist & Head, Division of Natural Resources, ICAR- CAZRI, talked about the mechanism, consequences of ozone layer depletion. The webinar was attended by the officials and researchers from the institute and the universities.

150th Birth Anniversary of Mahatma Gandhi

Organized an online Painting competition on October 02, 2020 for the school students of class X-XII on the theme "*The Father of the Nation Mahatma Gandhi & Environment*" A schedule was widely circulated to schools on their respective e-mail ids and social media platform. In total 24 students from various schools participated and submitted their paintings online. E-certificates sent to the winners as well as certificate of participation to all the participants.

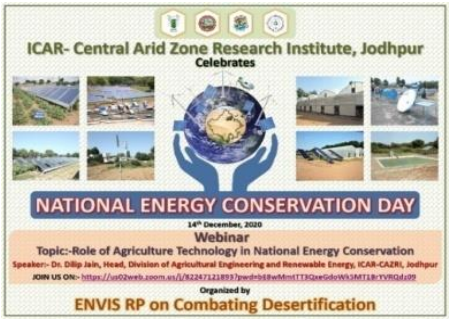


World Children's Day

Celebrated World Children's Day on November 20, 2020 through online poster competition for school children in two groups (Class V – VII with a theme "*Our Life during COVID - 19*") and (Class VIII – X with a theme "*A Day to Re-imagine a Better Future for Every Child*"). 14 students from various schools participated and submitted their posters online. E-certificates were sent to the winners as well as certification of participation to all the participants.

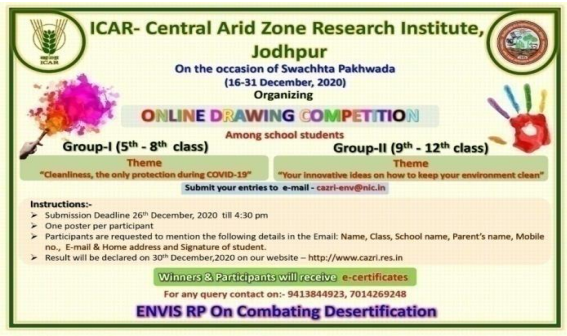
National Energy Conservation Day

Celebrated the National Energy Conservation Day on December 14, 2020 through a webinar on this year's theme "*Role of Agriculture Technology in National Energy Conservation*". The Guest Speaker, Dr. Dilip Jain, Principal Scientist & Head, Division of Agricultural Engineering and Renewable Energy, ICAR- CAZRI, Jodhpur elaborated the objective how to drive mass awareness about the importance of energy conservation. He highlighted the role of Agriculture Technology in National Energy Conservation through solar thermal processing units and solar gadgets. Dr. Pratibha Tewari, Principal Scientist & Head, Division of Transfer of Technolgy & Training, ICAR-CAZRI, addressed the session by focusing the pioneer role of ICAR-CAZRI in the field of energy conservation, water conservation correlated to agriculture and which is appreciated throughout India. 36 participants marked their presence during the webinar.



Swatchta Pakhwada

Organized an online Drawing competition during Swachhta Pakhwada on December 26, 2020 for school children in two groups viz. Group-I :- (Class 5th – 8th) with a theme "*Cleanliness the only Protection during COVID-19*" and Group-II :- (Class 10th – 12th) with a theme "*Your Innovative Ideas on How to Keep Your Environment Clean*". In total 210 students from various schools participated online. E-certificates were given to the winners as well as certificate of participation to all the participants.



Conferences

DATE	TOPIC	ORGANIZATION	PLACE
National			
17th - 19th July, 2020	National Web- Conference on Agricultural Resource Management for Atmanirbhar Bharat	Central Agricultural University, Imphal	Imphal, India
16th - 17th August, 2020	National Web – Conference on Technological Approaches for Resource Conservation & Management for Environmental Sustainability	Academy of Natural Resource Conservation & Management, Lucknow	Lucknow, India
21th September, 2020	The National Conference on Agriculture for Rabi Campaign	Department of Agriculture, Cooperation & Farmers Welfare (DAC&FW), Ministry of Agriculture & Farmers Welfare, Government of India	New Delhi, India
International			
22th - 24th July, 2020	International webinar on Achieving Land Degradation Neutrality	Indian Association of Soil and Water Conservationists (IASWC)	Dehradun, India
27th - 28th August 2020	The 7th International Conference on Agriculture	The International Institute of Knowledge Management (TIIKM), Sri Lanka	Bangkok, Thailand
11th- 12th September, 2020	International Web- Conference on Resource Management and Biodiversity Conservation to achieve Sustainable Development Goals	Academy of Natural Resource Conservation and Management (ANRCM), Lucknow	Lucknow, India